

ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 34

DECIBEL MEASUREMENT EXPERIMENTS



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HOME STUDY SCHOOL
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Experiment Lesson 34

INTRODUCTION

You studied the theory of decibels in Theory Lesson 26 and you learned something about the practical application of decibels in The Service Practices Booklets dealing with public address systems. This lesson gives you an opportunity to actually work with decibels.

You will prepare a calibration graph with which you can convert a-c voltage readings into decibels. You will learn about an ingenious device called a *constant-impedance attenuator*, which is much used in electronic circuits when voltage and power are measured in decibels. You will construct a constant-impedance attenuator, study its constant impedance and its attenuation qualities, and then you will use it to check the ability of your multimeter to measure quantities of voltage and power in decibel units.

EQUIPMENT NEEDED

Two 82-ohm $\frac{1}{2}$ -watt resistors
 Two 150-ohm $\frac{1}{2}$ -watt resistors
 One 680-ohm $\frac{1}{2}$ -watt resistor
 One 1,500-ohm $\frac{1}{2}$ -watt resistor
 One 470-ohm $\frac{1}{2}$ -watt resistor
 Radio chassis
 Multimeter
 Hookup wire
 Resistor board

EXPERIMENT 34-1

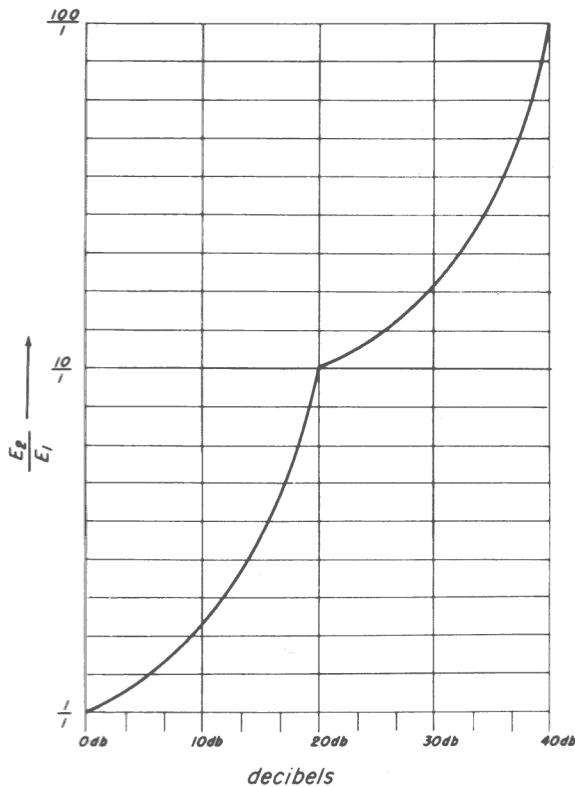
To prepare a decibel calibration graph for use with your multimeter.

Information. At the end of this lesson, you will find a sheet of graph paper labeled CALIBRATION GRAPH. Cut out this sheet of graph paper before you read further. The type of graph paper you just cut out is called *logarithmic graph paper* because the coordinates are spaced at unequal intervals corresponding to a logarithmic rate of change. This particular graph paper is called *semi-logarithmic* (*semi* means half) because only the horizontal coordinates are spaced logarithmically; the vertical coordinates are spaced equally.

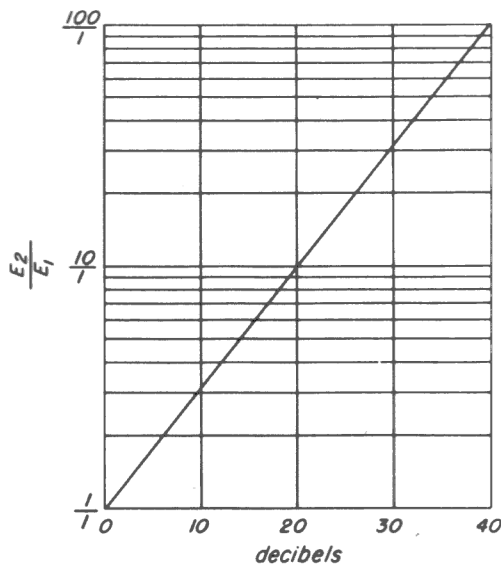
Note: This is the third kind of graph paper that you have learned about. You have already learned about ordinary graph paper with equally spaced rectangular coordinates, and about graph paper with polar coordinates.

For your convenience, on the graph you have just cut out we have printed decibel markings along the horizontal axis of the semilogarithmic graph paper, and voltage markings along the vertical axis. If you bought a sheet of this paper, it would not have these markings. However, even without the markings we have added, the graph paper can be used to solve some kinds of logarithmic formulas easily and quickly. Electronic engineers use commercially manufactured semilogarithmic graph paper for this purpose. Let's consider how it is used to solve the following logarithmic formula:

$$\text{db} = 20 \log \frac{E_2}{E_1}$$



(a)



(b)

Fig. 34-1

You will be able to understand the advantages of logarithmic graph paper better if you compare Fig. 34-1a with Fig. 34-1b. Figure 34-1a is a graph showing the number of db that correspond to various values of the ratio E_2/E_1 . It is drawn on ordinary

equal-spaced rectangular coordinate graph paper. The graph line comes out curved; it always comes out curved when a logarithmic formula is plotted on ordinary graph paper.

In Fig. 34-1b, the *same graph* is plotted on semilogarithmic paper. The line on the graph comes out straight. (If you wish to be sure that the two graphs are the same, look up various values of the ratio E_2/E_1 and observe that both graphs show these values to equal the same number of decibels. For example, both graphs show that, when the ratio E_2/E_1 is 10/1 it equals +20 db.)

Since the line on Fig. 34-1b comes out straight, the graph can be drawn by solving the formula for only two values of E_2/E_1 , plotting these two points on the graph paper, connecting them with a straight line, and extending the line if necessary. This done, the formula can be solved from the graph to find the number of decibels that correspond to any other value of E_2/E_1 . A good deal of arithmetic work can be avoided in this way. With ordinary graph paper, it is not possible to plot a graph in this way.

You recall that the decibel is a unit to measure gain or loss and can be used alone for this purpose. But you are going to use your meter measure *quantities* of power (power level) in decibels and not merely decibel gain and loss. When you measure power level in decibels, you must choose some quantity of watts or milliwatts as a power reference and then you can say that other quantities of power are so many db above or below the reference. Two standard power reference quantities are in common—6 milliwatts (0.006 watts) and 1 milliwatt (0.001 watt).

Next, you must choose a resistance reference. This is because you are going to measure values of voltage and call them power decibels. Values of voltage can only be equal to particular quantities of power when the voltage is measured across one particular value of resistance. The most common standard reference resistances are 500 ohms and 600 ohms.

Let us calibrate the a-c voltage scales of the multimeter for decibels by using 6 mw and 500 ohms as our references. Now we must find out the decibel numbers which correspond to all values of voltage that can be read from the meter scales. You can understand what a tedious task it would be to solve the formula $db = 20 \log E_2/E_1$ for every voltage division of the meter scale. Fortunately, we can draw a graph on the semilog paper to solve the formula for all the voltage divisions of the meter scale. To do so, we must know the decibel equivalent of at least two voltages.

Since 6 mw is the reference, we know that 0 db to the reference 6 mw = 6 mw. We can find the corresponding voltage across 500 ohms (the resistance reference) as follows:

$$P = \frac{E^2}{R}$$

$$0.006 = \frac{E^2}{500}$$

$$E^2 = 3$$

$$E = \sqrt{3}$$

$$= 1.73 \text{ volts}$$

Thus we have one point to plot on our graph — 0 db = 1.73 volts. For the other point, let us solve the formula to find the decibel equivalent of 17.3 volts.

$$\begin{aligned} \text{db to the reference 6 mw} &= 20 \log \frac{E_2}{E_1} \\ &= 20 \log \frac{17.3}{1.73} \\ &= 20 \log 10 \end{aligned}$$

Since Log 10 is 1:

$$\begin{aligned} \text{db to the reference 6 mw} &= 20 \times 1 \\ &= 20 \end{aligned}$$

So, 20 db = 17.3 volts. Now let us plot the graph.

Procedure.

Step 1. On the semilog graph paper that you cut out of the end of this lesson, pencil mark the intersection of the coordinate labeled 0 db and the coordinate labeled 1.73 volts.

Step 2. Pencil mark the intersection of the coordinate labeled 20 db and the coordinate labeled 17.3 volts.

Step 3. Line up a straight-edge ruler on the two points and draw a straight line across the graph paper, from border to border.

Discussion. The graph you draw should look like Fig. 34-2. From the graph, you can find the power in decibels to the reference 6 mw that is equivalent to any a-c voltage reading on your meter. For example, the graph shows that a 6 volt a-c reading means 11 db to the reference 6 mw in 500 ohms. It is possible to draw lines on the graph to represent decibel levels with reference to any combination of power and resistance reference levels.

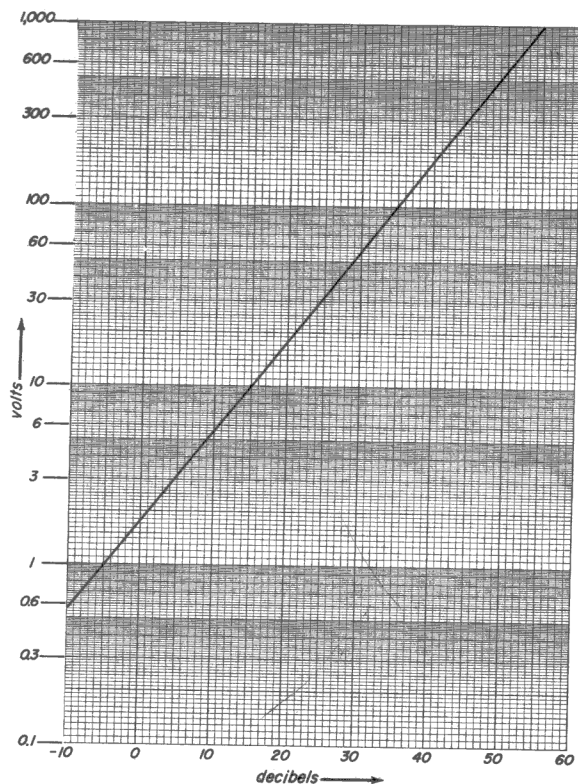


Fig. 34-2

EXPERIMENT 34-2

To calibrate a meter decibel scale using the calibration graph that you have prepared.

Information. Figure 34-3 shows the 15 volts a-c scale of your meter. A corresponding decibel scale has been drawn below it but the decibel numbers are omitted from the scale. In this experiment, you will fill in the numbers on the blank decibel scale.

Procedure.

Step 1. The center mark in Fig. 34-3 represents the point at which the meter pointer pivots. Lay a straight-edge ruler on the figure so that it intersects the center mark and one of the unnumbered markings on the db scale. The line made by the edge of the ruler represents the meter pointer. Look to see what value of voltage the meter will be indicating on the 15 VAC scale when the pointer is at the decibel marking that your ruler now intersects.

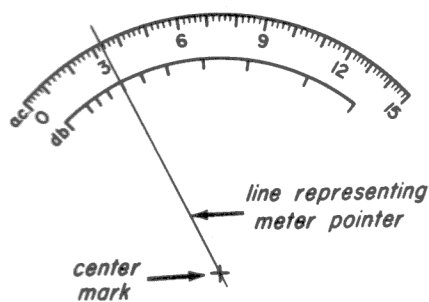


Fig. 34-3

Step 2. Look up this value of voltage on the graph that you have drawn in Fig. 34-2. From the graph, find what number of decibels this voltage corresponds to.

Step 3. Write this number of decibels below the unnumbered mark in Fig. 34-3 that you have intersected.

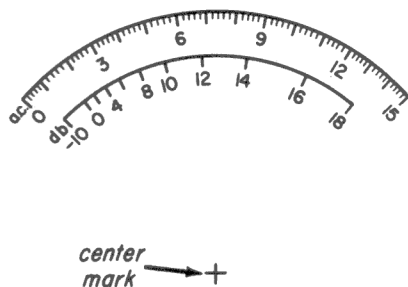


Fig. 34-4

Step 4. Repeat Steps 1, 2, and 3 for every unnumbered mark on the db scale in Fig. 34-3.

Step 5. When you have finished, check your results against Fig. 34-4.

Discussion. The decibel scale that you have calibrated corresponds to the 15 VAC scale on your meter. It holds true only when you are making measurements with the meter range switch set on the 15 VAC range. When your meter is set on the 75 VAC range, you must add 14 db to the reading on the decibel scale. On the 300 VAC range you must add 26 db. For example, if the pointer comes to rest at the zero db mark and your meter is set on the 75 VAC range, the reading is (0+14) or 14 db. And a reading of 10 db on the 300 VAC range must be corrected to (10+26) or 36 db.

You can see why the 14 db correction factor is used if you examine your scale. When the pointer is at the 5 db mark on the db scale, it intersects the 15 VAC scale near the 3 volt mark, and 3 volts = 5 db. At the same time, the pointer intersects the 75 VAC scale at the 15 volts mark, but 15 volts = 19 db. Therefore, 14 db must be added to the 5 db reading to get 19 db.

The decibel scale that you have calibrated holds true only when the impedance is 500 ohms across the two circuit terminals to which you touch your meter probes. When the impedance is *lower* than 500 ohms, you must *add* a number of decibels; when it is *higher*, you must *subtract* a number of decibels. Although you will not need to add or subtract decibels in this lesson, the number of decibels to add or subtract can be figured out from the following formula:

$$\text{db} = 10 \log \frac{R}{500}$$

where

R = the impedance across which you are measuring.

As a rule of thumb, subtract 3 db for every time the impedance is doubled; add 3 db for every time the impedance is halved. For example, if the impedance is 1,000 ohms,

it is doubled once ($500 \text{ ohms} \times 2 = 1,000 \text{ ohms}$); therefore, subtract 3 db. If the impedance is 2,000 ohms, it is doubled twice ($500 \text{ ohms} \times 2 \times 2 = 2,000 \text{ ohms}$); therefore subtract 6 db, etc.

JOB 34-1

To construct a constant-impedance 9-db attenuator board.

Information. The attenuator that you will construct is a network of resistors. To mount the resistors, you will make use of the resistor board that you made early in the course.

Procedure.

Step 1. Unsolder and remove all resistors from the board.

Step 2. Wire a 6-db attenuator and a 3-db attenuator as shown pictorially in Fig. 34-5a. A schematic is shown in Fig. 34-5b.

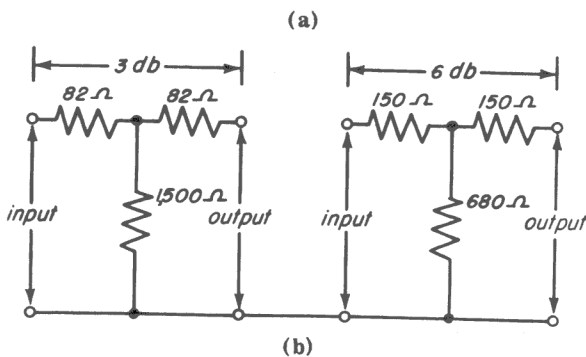
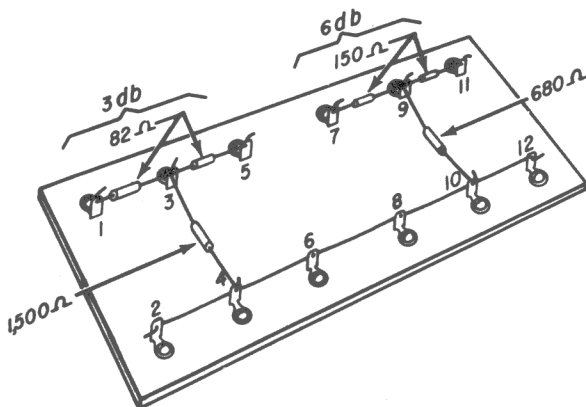
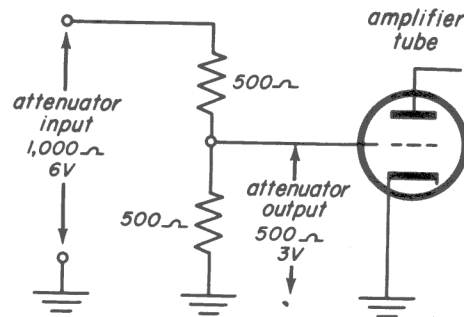


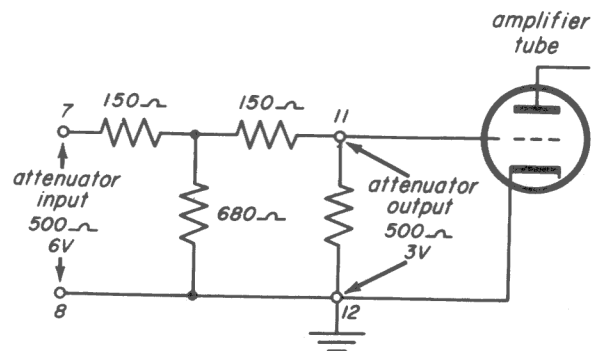
Fig. 34-5

EXPERIMENT 34-3

To study the constant impedance-quality of the attenuator board you constructed in Job. 34-1.



(a)



(b)

Fig. 34-6

Information. An attenuator is a device to reduce voltage or power. Its output must be less than its input. A simple resistance voltage divider is an attenuator. As shown in Fig. 34-6a, the output voltage from a divider (R_1 and R_2) is less than its input. However, the resistance across the input of the divider shown is 1,000 ohms while the amplifier grid resistor across which the output voltage develops is 500 ohms.

In Fig. 34-6b your 6-db attenuator is shown connected to the same amplifier grid resistor. Here the resistance across the input terminals (7 and 8) of the attenuator is 500 ohms, the same amplifier input resistance that would be presented by the 500-ohm grid resistor if the attenuator were not in place. Still, your attenuator reduces the 6 volts applied to 3 volts as in the case of the divider in Fig. 34-6a. This is what is meant by the term constant impedance as applied to your attenuator – that its input resistance is equal to the resistance across its output terminals.

In this experiment, you will compute the input resistance of the attenuator and see that this comes out equal to the resistance

across the attenuator output. Next you will measure the input resistance and see that it is, in fact, equal to the value of a resistor connected across the attenuator output terminals. Your attenuator is designed to have an input resistance of 500 ohms when 500 ohms is across its output terminals. Its constant impedance quality will not hold true for any other value of impedance.

Procedure.

Step 1. In Fig. 34-7a, the attenuator circuit schematic has been drawn to emphasize the series and parallel resistance combinations across the attenuator input terminals (7 and 8). To find the total resistance of R_1 and R_2 in series, add the two resistances and write the total here:

ohms

Step 2. Considering R_1 and R_2 as a single resistor ($R_1 + R_2$), the circuit can be drawn as in Fig. 34-7b. Find the total resistance of R_3 in parallel with $R_1 + R_2$, by using the parallel resistance formula:

$$R \text{ total} = \frac{R \times R}{R + R}$$

Write your answer here:

ohms

Step 3. Considering the total parallel resistance as a single resistor, the circuit can be drawn as in Fig. 34-7c. To find the

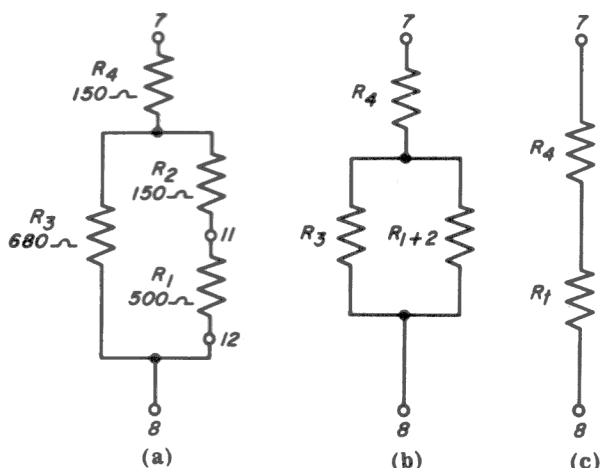


Fig. 34-7

input resistance of the attenuator network, add the total parallel resistance (R_t) to R_4 . Write your answer here:

ohms

Discussion. The input resistance you computed should be 482 ohms. The reason it is not exactly 500 ohms is that, using standard commercial resistors, it is not practicable to make the network to come out exactly 500 ohms. The attenuator was designed by figuring out what the resistances ought to be and then taking the nearest standard value.

Step 4. The standard resistor value nearest to 500 ohms is 470 ohms. Measure the resistance of your 470 ohms $\frac{1}{2}$ -watt resistor and write the meter reading here:

ohms

Step 5. Connect the 470 ohms resistor across the output terminals of your 6-db attenuator — terminals 11 and 12 of the resistor board.

Step 6. Measure the resistance across the input terminals (7 and 8) of the 6-db attenuator and write the meter reading here:

ohms

Discussion. The resistance across the input terminals of your 6-db attenuator is practically 500 ohms when the attenuator is terminated in approximately 500 ohms. Therefore, if you connect the input terminals of your terminated 6-db attenuator to the output terminals (5 and 6) of your 3-db attenuator, this is equivalent to terminating the 3-db attenuator in 500 ohms. Under these conditions, the resistance across the input terminals (1 and 2) of the 3-db attenuator should be practically 500 ohms.

Step 7. To interconnect the output and input terminals of the two attenuators, solder a jumper wire from terminal 5 to terminal 7 of the resistor board. (Terminals 6 and 8 are already connected together.)

Step 8. Measure the input resistance across terminals 1 and 2 of the 3-db pad. Write the meter reading here:

ohms

Discussion. As you see, a number of constant-impedance attenuators can be connected in tandem without changing the input impedance of the network. You can use either the 3-db attenuator or the 6-db attenuator alone, or you can connect them in tandem to make up a 9-db attenuator and still have a 500-ohm input.

In this experiment you studied the impedance of the 6-db network by using the rules for computing series and parallel resistance. In the next experiment you will study the attenuation property of the attenuators by computing the division of voltages across the resistors of the attenuator network. Although the attenuators can be studied in this way, they cannot readily be designed by this trial and error process. Constant impedance attenuators are designed by means of special formulas. A study of attenuator design is outside the scope of this course.

EXPERIMENT 34-4

To study the attenuation properties of a constant-impedance attenuator.

Information. Your 6-db attenuator reduces whatever voltage or power is put into it by a factor of 6 decibels. If you look at the decibel tables in Theory Lesson 26, you will see that, when a voltage is reduced 6 decibels, it is halved; when a power is reduced 6 decibels, it is quartered. Study the computations that follow and you will see that your 6-db attenuator approximately halves the input voltage and approximately quarters the input power.

Assume that a 6-volt generator is connected to the input terminals of the attenuator pad, as shown in Fig. 34-8. We want to compute the power input, the power output and the voltage output. We know that the total resistance across the input terminals of the pad is 500 ohms. The input power is computed as follows:

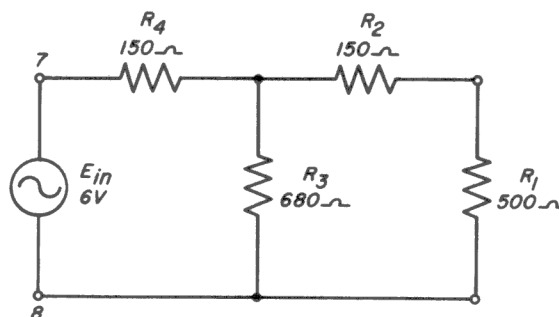


Fig. 34-8

$$\begin{aligned}
 P &= \frac{E^2}{R} \\
 &= \frac{(6)^2}{500} \\
 &= \frac{36}{500} \\
 &= 0.072 \text{ watts}
 \end{aligned}$$

The total current flowing in the network from terminal 7 to terminal 8 is as follows:

$$\begin{aligned}
 I &= \frac{E}{R} \\
 &= \frac{6}{500} \\
 &= 0.012 \text{ amperes}
 \end{aligned}$$

In order to get from terminal 8 to terminal 7, the full current must flow through R_4 . Therefore the voltage drop across R_4 is as follows:

$$\begin{aligned}
 E &= IR \\
 &= 0.012 \times 150 \\
 &= 1.8 \text{ volts}
 \end{aligned}$$

Since the voltage across R_4 is 1.8 volts, the remainder of the 6 volts must be across the series combination of R_1 and R_2 . The total voltage across R_1 and R_2 must be 4.2 volts. Of this total $\frac{150}{650}$ of the total voltage is across R_2 , and $\frac{500}{650}$ of the total voltage is across R_1 , the resistance in which the attenuator output develops. And so the output voltage is $\frac{500}{650} \times 4.2$ volts or 3.2 volts, which is approximately half of the 6-volt input.

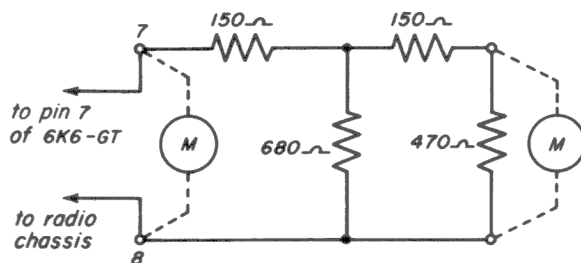


Fig. 34-9

The output power developed in R_1 (500 ohms) is as follows:

$$P = \frac{E^2}{R} = \frac{(3.2)^2}{500} = \frac{10.24}{500} = 0.02 \text{ watts}$$

The output power of 0.02 watts is approximately one quarter the input power, which is 0.072 watts (almost 0.08 watts). Now you will make measurements to prove that the output voltage is half of the input voltage.

Procedure.

Step 1. Open up the jumper wire connecting terminals 5 and 7 of the resistor board.

Step 2. Connect a wire from terminal 8 of the resistor board to the chassis of your radio. Connect another wire from pin 7, the filament pin of the 6K6 tube in your radio, to terminal 7 of the resistor board, as shown in Fig. 34-9. In this way, you apply 6 volts a.c. across the input terminals of your 6-db pad.

Step 3. Turn on your radio. Allow it to warm up for a minute. Then measure the input voltage between terminals 7 and 8 of the resistor board. Use the 15 VAC range of your

multimeter. Write the meter reading here:

volts a.c.

In our laboratory, we got a reading of 6 volts a.c.

Step 4. Now, measure the output voltage between terminals 11 and 12 of the resistor board. Write the meter reading here:

volts a.c.

We got a reading of 3 volts a.c.

EXPERIMENT 34-5

To check the decibel calibration of your multimeter by means of the attenuation pads that you have made.

Procedure.

Step 1. Connect a jumper wire between terminals 5 and 7 of the resistor board.

Step 2. Connect terminal 2 of the resistor board to your radio chassis. Connect terminal 1 to pin 7, the filament pin of the 6K6 tube in your radio.

Step 3. Examine Fig. 34-10 and, referring to the calibration graph, Fig. 34-2 or to the calibrated decibel scale, Fig. 34-4, measure the db level at the input (terminals 1 and 2)

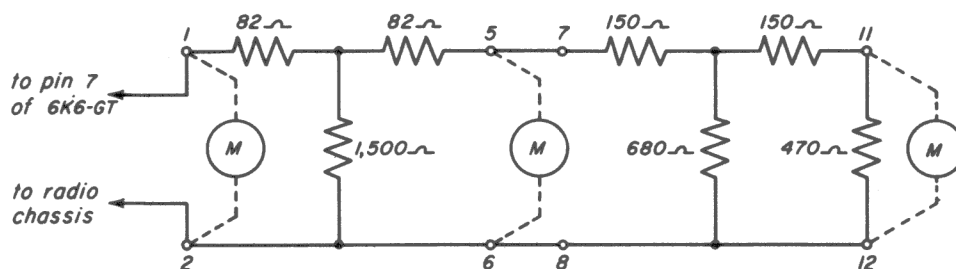


Fig. 34-10

of your 3-db pad. Write your reading here:

db above 6mw

In our laboratory, we got a reading of 11 db above 6 mw.

Step 4. Measure the decibel level at the output of your 3-db pad across terminals 6 and 5. Write your reading here:

db above 6mw

We got a reading of 8 db above 6 mw.

Note. The decibel output level of the 3-db pad is, of course, the decibel input level of the 6-db pad.

Compute how many db less is the output level of the 3-db pad measured in Step 4 than the input level measured in Step 3.

Write your answer here:

db

Step 5. Measure the decibel level at the output of the 6-db pad across terminals 11 and 12 of the resistor board. Write your reading here:

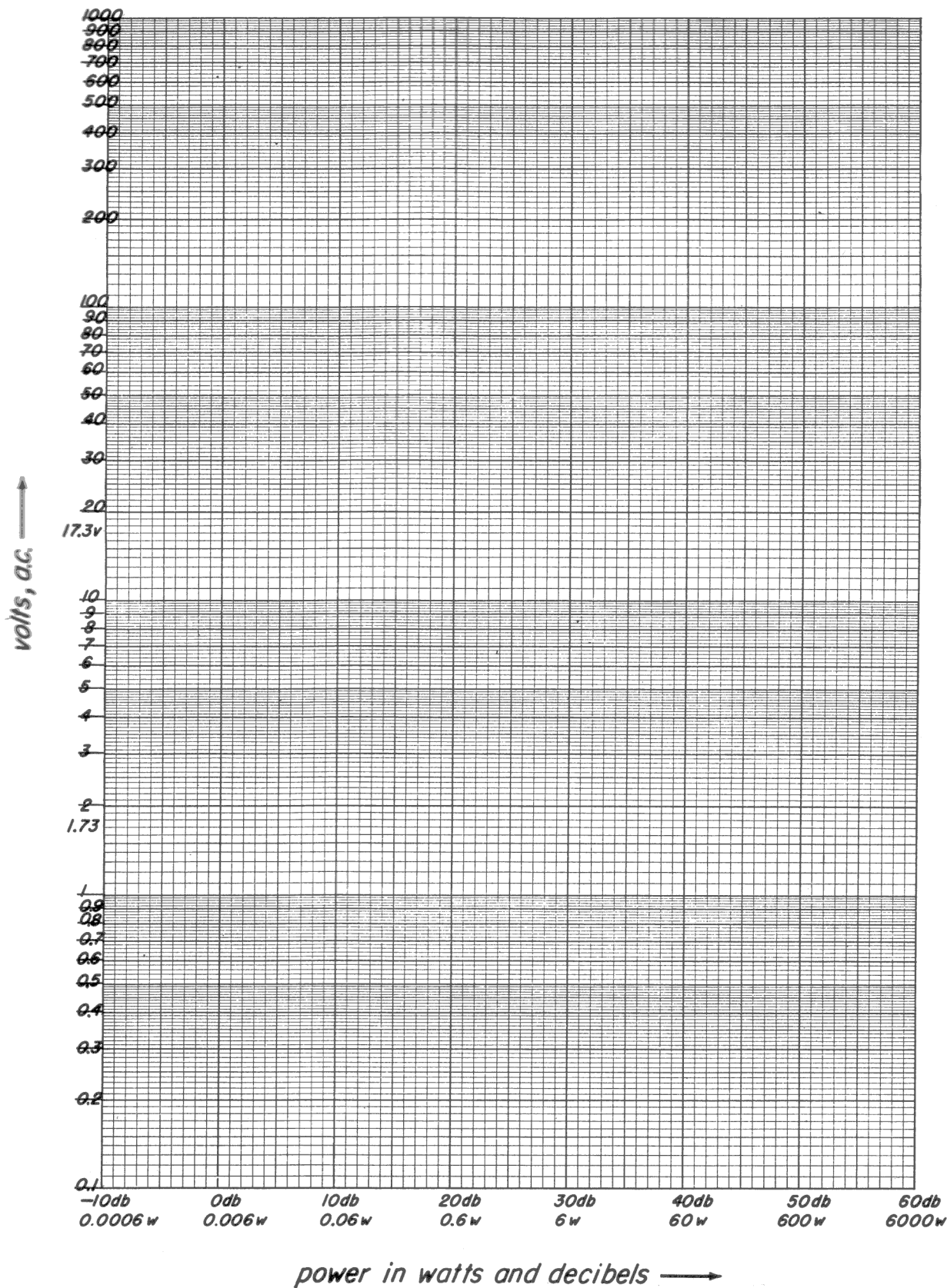
db above 6mw

We got a reading of 2 decibels above 6 mw.

Compute how many db less is the output level of the 6-db pad measured in Step 5 than the input level measured in Step 4. Write your answer here:

db





CALIBRATION GRAPH